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Spatial correlation of low latitude electron content for solar minimum

P K Bhuyan

Department of Physics, Dibrugarh University, Dibrugarh-786 004, Assam, India

and

T R Tyagi

Radio Science Division, National Physical Laboratory, New Delhi-110 012, India

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Abstract : Ionospheric electron content (IEC) measured simultaneously along a chain of Indian stations in and around the northern equatorial anomaly crest during 1975-76 were compared to study the magnitude and correlation of its variability with latitude and longitude. Results indicate that the absolute value of IEC obtained simultaneously at two locations longitudinally closer and equal distances away from the equator are identical at all local times and season. However, for large longitudinal separation of the observing stations, absolute IEC at one location were found to deviate systematically with season from those obtained at the other. Correlation of IEC between any two sets is a function of local time and decreases with increasing longitude and latitude separation. It has also been observed that the correlation in both east-west and north-south directions is comparable to those obtained at midlatitudes for shorter (~ 250 km) longitude/latitude separation but is lower for greater distances. Day-to-day variability in equatorial electrojet which influences the absolute value of IEC at the anomaly belt to varying degrees is believed to be primarily responsible for this lowering of correlation.

Keywords : Ionospheric electron content (IEC), correlation with latitude and longitude, equatorial electrojet.

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1. Introduction

The study of correlation of ionospheric electron content (IEC) at pairs of locations is considered important for the purpose of prediction of IEC at a place where no observational facility exists. In an earlier communication (Bhuyan *et al* 1984), we had reported that the magnitude of two simultaneously observed sets of IEC at the northern edge of the Appleton anomaly (26°N) depends critically on the location of the two subionospheric points. It had been further observed that the correlation between the two sets of IEC is a function of local time and is lower compared to the values obtained for identical longitude separation at midlatitudes. A number of workers (Kane 1982, Singh and Gurm 1979, Dabas et *al* 1984) have investigated various aspects of the variability in IEC at different time space configurations. However, spatial correlation of IEC have been studied only by a few workers so far (Klobuchar and Johanson 1977, Kane 1982, Soicher et *al* 1983, Huang 1984). Klobuchar and Johanson (1977) had observed that at midlatitudes the correlation of mean daytime IEC decreases with increasing longitudinal and/or latitudinal separation of the monitoring stations. Similarly, Kane (1982) had shown that at American midlatitudes the change in IEC at locations few hundred kilometers apart might be as much as 30-50 per cent. At low latitudes, variations in the equatorial electrojet strength influences the day-to-day variability in IEC to a large extent (Dabas et *al* 1984). A quantitative analysis of the variability effect at low latitudes had been attempted by Huang (1984) and Bhuyan and Tyagi (1989).

The aim of this paper is to investigate the effect of latitude and longitude separation on IEC correlation in the Indian low latitude region using a larger data base covering almost the entire subcontinent in the north-south and east-west directions.

2. Data

The IEC data used in this analysis were obtained by monitoring the Faraday rotation angle of 140 MHz beacon transmissions from the ATS-6 satellite during its phase-II

Table I. Coordinates of observing stations and their subionospheric points at 300 km for satellite ATS-6 (0 °N, 35 °E).

Location	Geographic			Subionospheric		
	Lat., °N	Long., °E	Approx. Dip., °N	Lat., °N	Long., °E	Approx. Dip., °N
Bombay	19.1	72.9	25.0	17.8	69.8	23.0
Rajkot	22.3	70.7	33.0	21.0	68.1	29.5
Ahmedabad	23.0	72.6	34.0	21.7	69.8	30.0
Udaipur	24.6	73.7	35.0	23.1	70.1	33.8
Gauhati	26.2	91.8	36.0	24.5	85.4	34.5
Patiala	30.3	76.4	46.0	28.3	72.1	43.0

campaign (September 1975-August 1976). The coordinates of the subionospheric points as well as the ground locations are listed in Table 1.

3. Results and discussion

3.1. Effect of longitude separation :

Sample plots of disturbed and quiet day variations of absolute IEC at two pairs of locations, viz. Ahmedabad-Rajkot and Gauhati-Udaipur are illustrated in Figure 1. Each of the two pairs of locations are at approximately equal distances from the magnetic equator (Table 1). Ahmedabad and Rajkot are closer in longitudes, less than 2° apart, while Gauhati and Udaipur pair has a longitude difference of 15° (Table 1). It is noted that the IEC measured at Ahmedabad and Rajkot match very

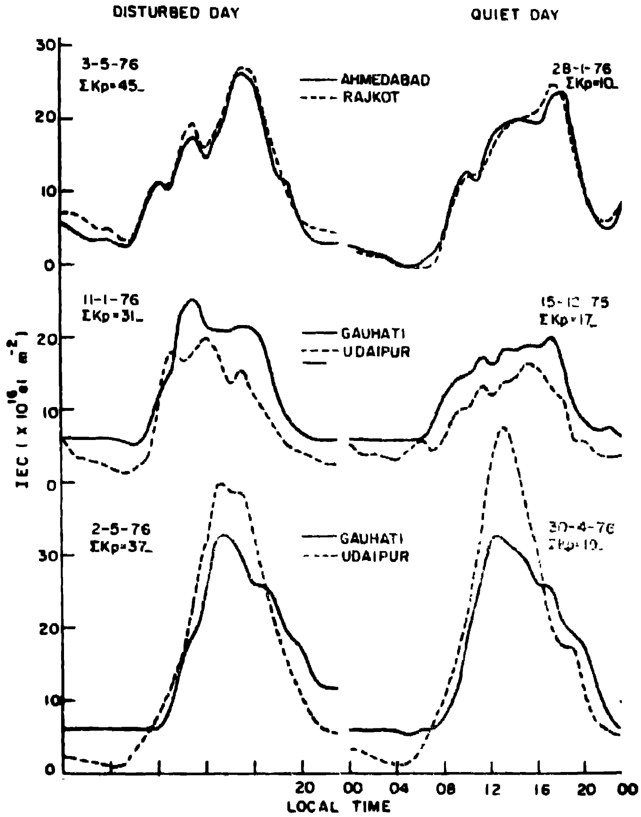

Figure 1. Diurnal variation of IEC on typical disturbed and quiet days for Ahmedabad-Rajkot (top row) and Gauhati-Udaipur pairs (middle and bottom row).

well while those at Gauhati and Udaipur do not. Absolute IEC values measured at Gauhati are higher than those obtained at Udaipur in winter whereas the reverse is true in spring, commonly in daytime hours. This point is further illustrated in Figure 2 where the mean monthly diurnal maximum and minimum IEC are plotted for both the pair of locations. For Ahmedabad and Rajkot, there is no marked difference in the two sets of IEC either in their maximum or minimum values. But IEC minimum values at Gauhati are higher all throughout than those at Udaipur while IEC_{max} values for Gauhati are higher in winter and lower in spring than those

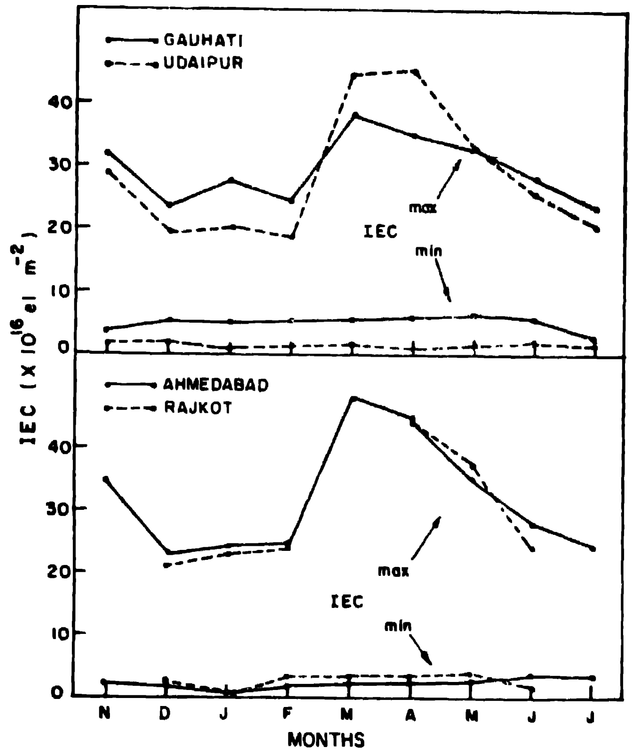

Figure 2. Plot of monthly mean maximum and minimum IEC for Gauhati and Udaipur (top panel) and Ahmedabad and Rajkot (bottom panel).

obtained at Udaipur. In summer, both the sets of IEC reach about equal maximum level. There is thus an indication of the discrepancy between the Gauhati-Udaipur sets of data being systematic and variable with season. From a plot of IEC at one location against those of another, a simple relationship of the type $y = mx$ can be expected provided there is no deviation of one set of IEC from the other. It might be further deduced from standard statistical analysis that a value of $m = 1 \pm 0.28$ is expected within a 95 per cent confidence limit. In Figure 3, the relative monthly mean hourly values of IEC, divided into winter, summer and spring, for Rajkot and Ahmedabad are plotted one against the other. The dashed lines in the figure on either side of the solid line ($m = 1$) represent the deviations of m by ± 0.28. Relative IEC i.e. ($IEC-IEC_{min}$) rather than its absolute value, are plotted to eliminate any possible calibration error in the data. It has been noted from the figure that the data points are evenly distributed around the solid line in all seasons. Thus there has been no systematic deviation of IEC at Rajkot from those measured simultaneously at Ahmedabad. On the other hand, a similar plot

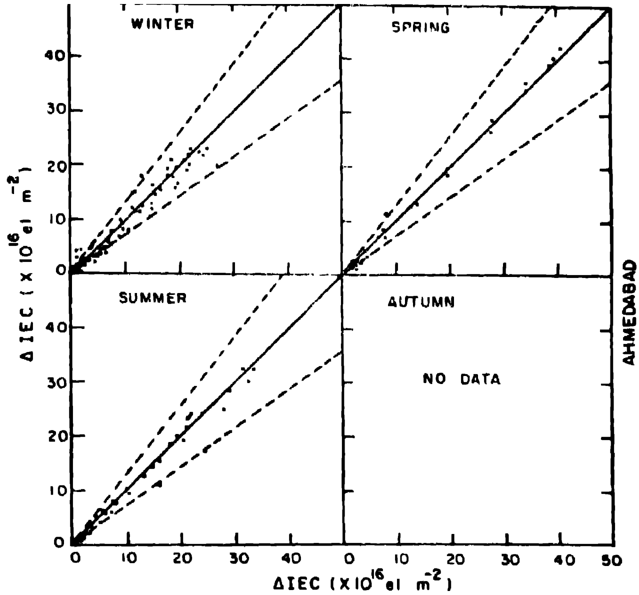

Figure 3. Mass plot of Δ IEC$_j^z$(IEC-IEC$_{min}$) at hourly intervals for Ahmedabad versus Rajkot in units of 10^{16} el m^{-2}.

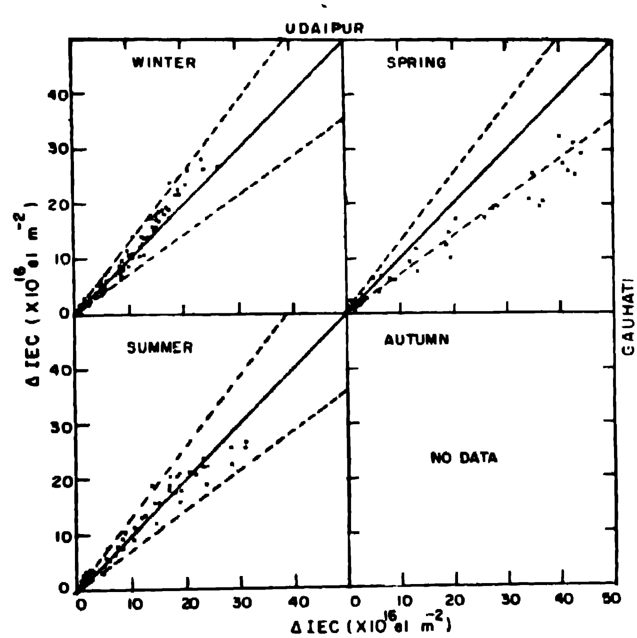

Figure 4. Δ IEC of one location against the other (Gauhati versus Udaipur).

between Gauhati and Udaipur IEC presents an entirely different picture in Figure 4. In winter, the data points, particularly the daytime values, are distributed along the Gauhati side of the solid line whereas in spring, the points lie along the dashed line on Udaipur side. In summer, the data points are evenly distributed around the solid line. The points clustered towards Gauhati axis in spring, which are mostly nighttime and morning hour values, indicate that absolute IEC at Udaipur overtake those of Gauhati during the daytime hours only. This was also evident in Figure 2. Thus the electron content measured simultaneously at these two locations systematically deviates from one another except in summer. Unfortunately, autumn data were not available to assess this phenomenon further. Varying electron density gradients seem to produce this discrepancy at these two locations separated by a large longitudinal distance while Ahmedabad and Rajkot being closer, do not show any such difference. Comparison of the present observation with our earlier report (Bhuyan et *al* 1984) indicates that the observed effect is true even for high sunspot activity years.

3.2. *Variability in correlation distance of IEC :*

In Figure 5 the diurnal variation of the annual mean correlation coefficients at two pairs of locations is shown. These two pairs were chosen as short and long distance separation of observing stations. Local time dependence of the IEC

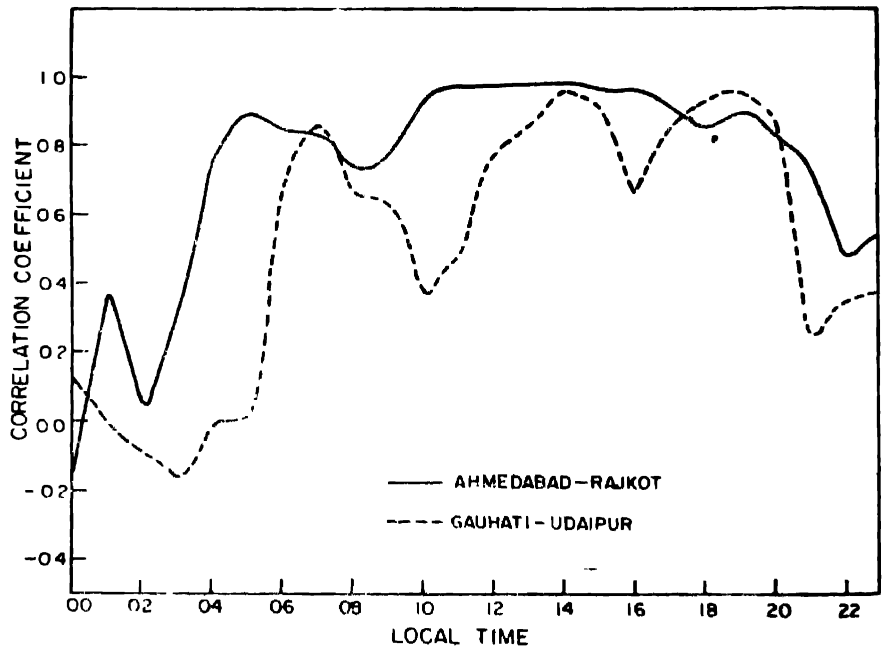

Figure 5. Diurnal variation of correlation coefficient of IEC observed at two pairs of locations.

correlation, as seen in the figure, is a feature common to any two sets of observations used in this study. It was also observed that the correlation is highest in the afternoon hours (1200-1600 LT) and lowest during nighttime (2300-0300 LT). Present results conform to our earlier observation (Bhuyan et *al* 1984) relating to high sunspot activity period. The diurnal curves bear good resemblance to those obtained by Soicher et *al* (1983) for European midlatitude stations. However, Huang (1984) had observed that, on an average, the correlation for nighttime (2330-0300 hour LT) is greater than that for daytime (1000-1600 hour LT) in the pacific anomaly crest region.

Figure 6 illustrates the average daytime (1000-1600 hour LT) values of the cross correlation coefficient obtained for stations, listed in Table 1, in the east-

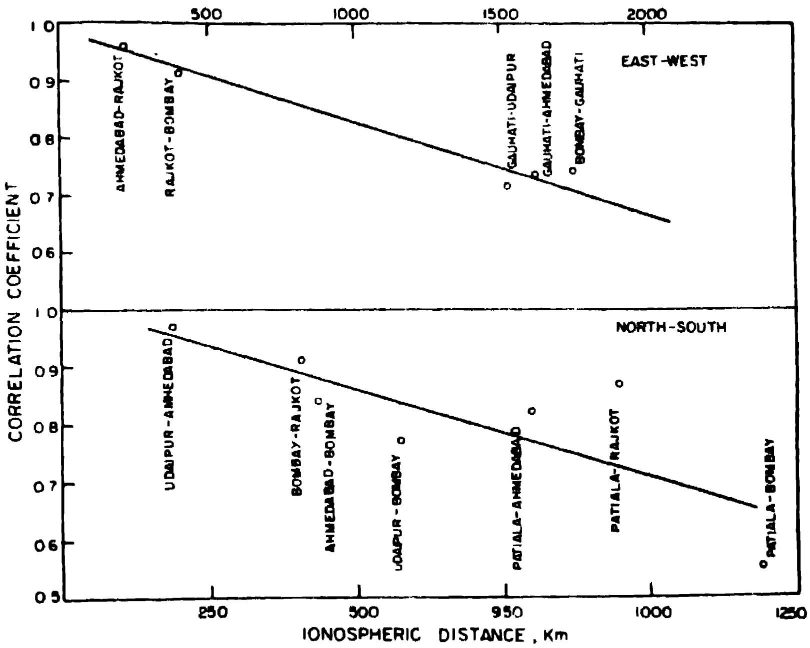

Figure 6. Correlation coefficient versus latitude/longitude separation of station pairs.

west and north-south direction. The correlation distance in the north-south direction was found to be shorter compared to that in the east-west direction. Following Klobuchar and Johanson (1977), it may be shown that the stations should be separated by 900 km in latitude and 1500 km in longitude for 50% reduction in uncertainty. When the present results were compared with those obtained at other latitudes (Table 2), it was found that for shorter distances (~250 km), the correlation coefficients were comparable at all locations, but for greater longitudinal and latitudinal separation, the correlation at low latitudes was lower than that observed at midlatitudes. Klobuchar and Johanson (1977) had reported that for 50% improvement in IEC prediction, the monitoring stations at midlatitudes should be located every 2400 km in the east-west and every 1600 km in the north-south direction or in other words, for comparatively longer (beyond 250 km or so) latitude/longitude separations, the correlation distance is shorter at low latitudes. This corroborates our earlier observations (Bhuyan *et al* 1984) at

Table 2. Correlation coefficient at different geographic locations.

Station pair	Ionospheric distance (km)		Correlation coefficient	Source
	Latitude	Longitude		
Ahmedabad-Udaipur	190	—	0.98	Present observation
Midlatitude (interpolated)	200	—	0.98	Klobuchar and Johanson (1977)
Lunping-Kaohsiung	280	—	0.89	Huang (1984)
Hawick-Aberystwith	300	—	0.88	Huang (1983)
Bombay-Patiala	1200	—	0.55	Present observation
Hamilton-Goosebay	1300	—	0.86	Klobuchar and Johanson (1977)
Rajkot-Bombay	—	400	0.91	Present observation
Midlatitude (interpolated)	—	400	0.96	Klobuchar and Johanson (1977)
Hamilton-Urbana	—	1500	0.88	—do—
Gauhati-Udaipur	—	1525	0.71	Present observation

two locations 900 km apart during the high sunspot activity period (1979). Huang (1984) had also observed that the average correlation of IEC at the crest of the northern equatorial anomaly is lowered by seasonal differences even when the station pair is situated as close as 280 km. Variability in the equatorial electrojet strength is well correlated with the variability in IEC at most of these stations included in the present analysis (Dabas *et al* 1984). Singh and Gurm (1979) had earlier shown that the effect of the electrojet strength on IEC varies with the location of the observing stations. This is perhaps one of the main reasons for lower correlation at equatorial latitudes as compared to that obtained at mid-latitude.

The data used in this analysis belong to the minimum of the solar cycle 21 and since then the minimum of the present solar cycle had occurred in 1985-86. The authors are fully aware of the fact that comparison of the present set of observations with a similar analysis of the data from the recent solar minimum would make this report more meaningful. Unfortunately, there were no collective effort for simultaneous IEC data collection in the Indian zone after the ATS-6 period and a similar study could not be undertaken for lack of data.

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References

Bhuyan P K, Singh L and Tyagi T R 1984 *Indian J. Radio Space Phys.* **13** 185

Bhuyan P K and Tyagi T R 1989 *Indian J. Radio Space Phys.* **18** 134

Dabas R S, Bhuyan P K, Tyagi T R, Bharadwaj R K and L J B 1984 *Radio Sci.* **19** 749

Huang T X 1983 *Proc. COSPAR/URSI International Satellite Beacon Symposium* ed T R Tyagi (New Delhi, India) p 403

Huang Y N 1984 *J. Geophys. Res.* **89** 9823

Kane R P 1982 *Ann. Geophys.* **38** 145

Klobuchar J A and Johanson J M 1977 *REP. AFGL-TR-77-0185 (Air Force Geophys Lab. Bedford, Mass. USA)*

Singh M and Gurm H S 1979 *Indian J. Radio Space Phys.* **8** 306

Soicher H, Klobuchar J A and Doherty P N 1983 *Proc. COSPAR/URSI International Satellite Beacon Symposium* ed T R Tyagi (New Delhi, India) p 409